tures of *E. affinis* is its extremely large size, particularly its weight of 13.15 kg, as this specimen represents the heaviest *E. affinis* documented. The previous documented record of maximum size for *E. affinis* was 11.79 kg based upon a specimen captured in Merimbula, NSW, Australia in 1980 (Anonymous 1986).

It is interesting that the maximum size records established for the black skipjack, *E. lineatus*, and the yellowfin tuna, *Thunnus albacares*, are based upon sport-caught specimens from the Revillagigedo group of islands. The fact that many species tend to be longer lived and reach maximum sizes in the northern latitudinal ranges of their distributions, apparently pertains to the aforementioned species of tunas, as well. In the case of this record specimen of *E. affinis*, although found outside its normal geographical distribution, the maximum size was attained in this same region of the Pacific Ocean.

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CONTRIBUTION TO THE LIFE HISTORY AND REPRODUCTIVE BIOLOGY OF GAG, *MYCTEROPERCA MICROLEPIS* (SERRANIDAE), IN THE SOUTH ATLANTIC BIGHT[1]

The gag, *Myceteroperca microlepis*, is a demersal serranid found along the southeastern coast of the United States and in the Gulf of Mexico (Smith 1971; Fischer 1978). Throughout its range the gag is of both commercial and recreational importance. Because of its relatively slow growth rate (Manooch and Haimovici 1978) and desirability, overfishing is of wide concern.

The gag is a protogynous hermaphrodite, and McErlean and Smith (1964) suggested that sexual transformation occurs during the 10th or 11th year. Spawning occurs from January to March off the west coast of Florida (McErlean 1963), and the maximum reported age is 13 years in both the Gulf of Mexico (McErlean 1963) and the South Atlantic Bight (SAB) (Manooch and Haimovici 1978). Microscopic examination of the gonads is necessary for definite sexual identification, but gonad morphology has not been specifically described. The purpose of this study is to provide new information on the age, growth, and reproductive biology of this important species, including a description of the morphology of gag ovaries and testes.

Methods

Most samples were obtained from the commercial hook and line fishery, and others were collected on research cruises aboard the RV *Dolphin*, RV *Oregon*, and RV *Lady Lisa* from 1976 to 1982. Specimens were measured (total and standard lengths), weighed, and sagittae removed from the otic capsule through the branchial chamber. Otoliths were stored dry and later viewed in a dish of cedar wood oil with reflected light over a dark background using a binocular microscope. Since opaque bands in larger otoliths were thin and often too crowded near the edge to permit accurate counting, cross sections (approximately 0.5 mm thick) were made on the dorsoventral plane of the otoliths through the center with a diamond dicing wheel mounted on an ISOMET[2] low speed saw. Sectioned otoliths were viewed in

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[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

the same manner as whole otoliths. If two readings by a single observer did not agree, otoliths were deleted from analyses. Additional verification of counts was then obtained from a second observer who read 200 otoliths (35%) selected randomly.

Because monthly samples did not contain similar porportions of large and small fish, calculations of monthly mean marginal increments of sagittae were biased. For instance, if primarily small fish are sampled in one month followed by mostly large fish in the next month, the mean marginal increment will decrease regardless of the time of year. To alleviate this bias, marginal increments were standardized by converting each measurement to a proportion of the maximum recorded for that age group. Thus, a measurement of 2.5 ocular units in an age group for which the maximum is 10.0 becomes equivalent to a measurement of 0.5 ocular units in an older group for which the maximum is 2.0.

Sex and reproductive conditions were determined from histological sections of gonads, which were preserved in 10% formalin, and later processed through an Autotechnicon Duo Model 2A automatic tissue processor, then embedded in paraffin, and sectioned with a rotary microtome at approximately 7 μm (Humason 1972). Tissues were then stained with Harris' hematoxylin and counterstained with eosin-Y. Sexes were identified as male, female, and hermaphroditic female or "transitional" (gonad primarily ovarian, with some traces of active testicular tissue present). Maturity was described following the synopses listed in Waltz et al. (1982). Terminology used in histological descriptions follow Hyder (1969), Combs (1969), and Wallace and Selman (1981).

Results

A total of 1,039 gag ranging in total length (TL) from 153 to 1,150 mm was examined for life history information. Of the 652 otoliths on which age determinations were attempted, 87% showed discernible rings verified by two readings. No otoliths were deleted from analyses because of disagreement between primary and secondary readers. Marginal increment measurements from the outer edge of the last opaque band to the dorsal margin of whole sagittae indicate that these bands are laid down in late spring to midsummer. Bands are apparently laid down earlier and over a longer time period (May-August) in ages ≤VIII than in older gag. Although sample sizes of fish ≥age IX on which marginal increments were measured are small in relation to those of younger gag, it appears that ring formation is concentrated in August (Fig. 1). Twenty-two age groups were identified (Table 1).

The gag ovary is a hollow, bilobed organ suspended in the posterior region of the body cavity from the swimbladder by mesenteries. Blood vessels and nerves enter the gonad at the anterior point of each lobe's suspension and course medially to the mesenteries along the dorsomedial surface of each lob. The lobes fuse posteriorly, their

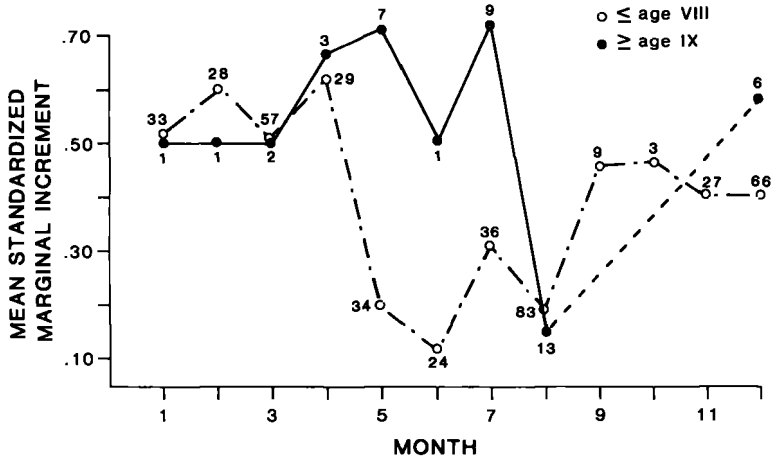

FIGURE 1.—Mean standardized marginal increments by month for gag ≤age VIII and ≥age IX, and sizes of monthly samples.

TABLE 1.—Observed mean lengths (mm), weights (kg), and sample size by age for *Mycteroperca microlepis*.

Age	Number	Total length (mm)	Standard length (mm)	Weight (kg)
0	14	187	153	0.087
1	17	347	293	0.605
2	18	466	383	1.263
3	26	575	470	2.104
4	49	677	555	3.881
5	80	767	641	5.558
6	102	824	686	6.040
7	91	865	729	7.612
8	51	895	751	8.454
9	21	936	789	9.810
10	19	959	807	10.491
11	23	993	826	11.399
12	7	1,004	841	13.327
13	4	1,048	884	14.950
14	2	1,066	905	13.000
15	2	1,096	927	14.748
16	9	1,064	905	14.495
17	10	1,076	904	14.767
18	10	1,068	887	14.310
19	5	1,087	924	14.074
20	5	1,071	896	15.150
21	1	1,125	950	15.400
22	1	1,124	946	—

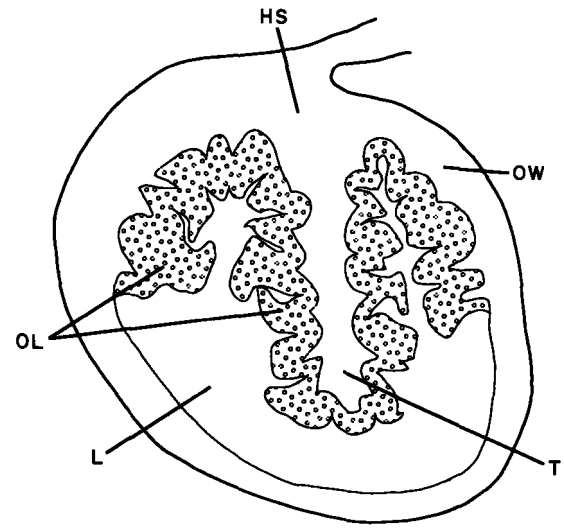

FIGURE 2.—Schematic representation of a cross-sectioned gag ovary (diameter = 3 cm). HS = halar stroma, L = lumen, OL = ovarian lamellae, OW = ovarian wall, T = "Typhlosole-type" invagination of the dorsal wall.

lumena forming a common oviduct. The lumena are incompletely lined with folded germinal epithelium (ovarian lamellae) within which oocytes develop and mature. The ventral regions of the lumena remain void of lamellae, and these alamellar areas are contiguous with the alamellar oviduct. In addition to the dorsal and lateral walls of the lumena showing lamellar development, there is a "typhlosole-type" continuation of the dorsal gonad wall projecting into each lumen. This projection of connective tissues into the center of the lumen apparently allows additional surface area for attachment of ovarian lamellae (Fig. 2).

During the sexual transition phase, testicular growth fills the existing ovarian lamellae, displacing and possibly dislodging the already degenerating oocytes. Transitional gonads were rarely found, and there were no cases of simultaneous development of gonad tissues. Male gonads retain the somatic morphology of the ovary. Testicular tissue is arranged in "false lamellae", primarily suspended from the "typhlosole-type" structure. Sperm sinuses form peripherally in what was previously the ovarian wall and continue posteriorly becoming the vas deferens within the oviduct wall. The vestigial ovarian lumena and oviduct remained in all testes examined. All testes also possessed many residual oocytes, some as large as 500 μm in diameter.

Females made up 84% of the gag which were sexed. Examining the percentage in each age class, we found that 28% of age III, 51% of age IV, and all older female gag had mature ovaries. Immature gag ranged from 290 to 680 mm TL, whereas the smallest mature female was 600 mm TL. Male gag accounted for 15% of the animals sexed and were found in ages V through XX (no sex available for age XXI and XXII fish). No males were found smaller than 790 mm TL (Fig. 3) and no juvenile males were found. Gag with transitional gonads made up 1.25% of all the groupers sexed and occurred in ages V through XI. The size range for fish undergoing sex succession was from 750 to 950 mm TL (Fig. 3).

The gag spawns once a year in late winter-early spring. Analysis of the relative abundance of developing, ripe, and postspawned gonads indicated that peak spawning activity was reached in late March and early April (Fig. 4) in the SAB.

Discussion

Use of whole sagittae in aging gag has been validated (McErlean 1963), and Matheson et al. (1986) successfully validated the use of sectioned sagittae to age the congeneric scamp, *Mycteroperca phenax*. These studies together with the present data provide good evidence that sagittal

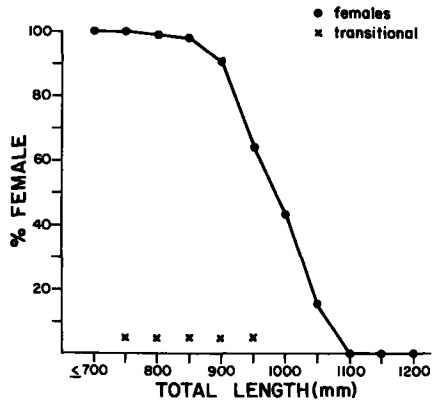

FIGURE 3.—Percent female gag by length class, and occurrence of transitional gag.

rings detected in the present study are annual in nature. While the importance of adequate validation has been well documented (Beamish and McFarlane 1983), it has become increasingly clear that annulus formation in many species can take place over an extended period, making it difficult to pinpoint this event in time. Peak annulus formation covered a 3-mo period for the groupers *Epinephelus drummondhayi* (speckled hind) and *E. niveatus* (snowy grouper) (Matheson and Huntsman 1984). Thus, the May-August period of peak ring formation for younger gag in the present study is not unusually long. Reasons for differences between ages ≤VIII and ≥IX in timing of peak annulus formation are not apparent. However, that the differences are at least partially based on sex is probable since the younger fish are predominately female while approximately 60% of the older group are male. A comparison strictly between sexes was not possible since samples of males available for measurement were obtained in only 5 months.

The use of sectioned sagittae greatly enhanced clarity among the higher age groups and allowed for greater distinction between rings in comparison to whole otoliths. Beamish (1979) found that sectioned otoliths of the Pacific hake, *Merluccius productus*, gave a more accurate account of age, especially when thick otoliths with poorly defined annuli were encountered. This appears to be true for the gag, as well. Twenty-two age groups were distinguished in the present study, similar to the 21 age groups reported for the scamp (Matheson et al. 1986), compared with previous reports of 13 age groups for the gag (McErlean 1963; Manooch and Haimovici 1978). The nine groups not detected previously do not represent just an increase in the percentage of readable otoliths (present study: 87%; McErlean 1963: 87%; Manooch and Haimovici 1978: 79%). Rather, it appears that additional annuli are present in the otoliths of the larger size classes that were not detected in previous studies using whole otoliths. For instance, the oldest fish collected by Manooch and Haimovici (1978) was age XIII and 1,201 mm TL, longer than any gag aged in the present study and 77 mm longer than the age XXII fish (Table 1).

Moe (1969) described the reproductive biology of the red grouper, *Epinephelus morio*, and many aspects of the development and sex succession schedules are similar to those found in the gag.

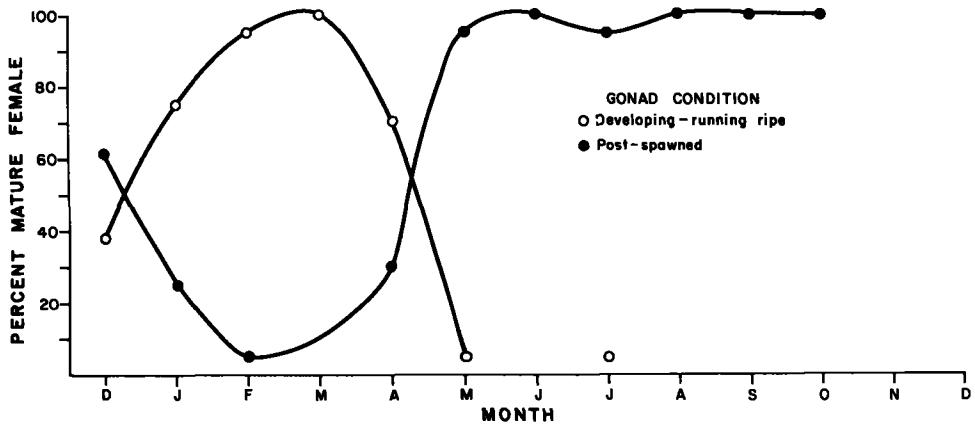

FIGURE 4.—Maturity stages of female gag by month of capture, illustrating the late winter-early spring spawning season.

The actual morphology of the gonad, however, differs from that described for red grouper. Moe (1969) cited Smith's (1965) description of an *E. fulvus* ovary, but Smith did not mention the "typhlosole-type" structure from which ovarian lamellae are suspended that was found in gag gonads in the present study. This structure is also found in *M. phenax*, *M. interstitialis*, *E. adscencionis*, *E. drummondhayi*, *E. flavolimbatus*, and *E. niveatus* (Roumillat, unpubl. data) and may be present in other groupers.

Although Moe (1969) found only 1.43% of red groupers undergoing sexual succession, the percentage of fish with transitional gonads was even lower in the gag (1.25%). These frequencies are much lower than the transitional frequencies of such sympatric species as *Centropristis striata* (14%; Wenner et al. 1986), *Calamus leucosteus* (10-13%; Waltz et al. 1982), *Pagrus pagrus* (10%; Roumillat, unpubl. data), and *Hemanthias vivanus* (9%; Hastings 1981). A rapid rate of sex succession is probably the reason for the low frequency of transitional gonads found. Smith (1965) and Moe (1969) suggested that other groupers have a very quick rate of succession, and Fishelson (1970) and Shapiro (1981) have shown that *Anthias squamipinnis* can change sex within a few weeks.

Despite suggestions that gag transform to males during their 10th or 11th year (McErlean and Smith 1964), it is evident that sexual succession occurs at younger ages. Only seven transitional gag were collected, and of the five that were aged, there was one each in age groups V, VI, VII, VIII, and XI. However, age X was the group in which the sex ratio approximated unity. The age of first maturity for females was lower than the previously speculated fifth or sixth year (McErlean and Smith 1964), and 28% of age III, 51% of age IV, and all older femal gag had mature gonads. Thus, there may be significantly more gag (all females because of protogyny) producing gametes than indicated in the literature, suggesting a greater ability to rebound from intensive overfishing than previously suspected.

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AGE AND GROWTH, REPRODUCTIVE CYCLE, AND HISTOCHEMICAL TESTS FOR HEAVY METALS IN HARD CLAMS, *MERCENARIA MERCENARIA*, FROM RARITAN BAY, 1974-75.

Raritan Bay has historically supported an abundant hard clam, *Mercenaria mercenaria* L., resource. It was considered the most important commercial species in the bay with an estimated total value of 34 million dollars in 1963 (Jacobsen and Gharrett 1967). Campbell (1967) reported a total standing crop of 4.8 million bushels of clams for the Bay for the same year (3.4 million bushels in New York waters and 1.4 million bushels off New Jersey). More recent estimates are unavailable.

Raritan Bay waters have historically received various domestic and industrial wastes, some of which have had adverse effects on its shellfish resources and fisheries. Raritan Bay was closed to harvesting of hard clams on 1 May 1961, after an epidemic of human infectious hepatitis was traced to the consumption of raw clams from the bay (Campbell 1967). The closure remains in effect to the present time. Zoellner (1977) reviewed the nationwide water quality problems related to shellfish and included Raritan Bay as one of the case studies in the report.

Bivalves accumulate various biological and chemical contaminants by mechanisms related to their filter-feeding habits and transport across their mucous-covered, semipermeable soft body tissues (Goldberg 1957; George 1982). The accumulation of heavy metals, pesticides, polychlorinated biphenyls (PCB's), oil and dispersants, disease causing bacteria, viruses, fungi, parasites, and toxic phytoplankton have serious public health implications and may also adversely affect bivalve resources. Zoellner (1977) has reviewed natural and manmade conditions affecting bivalve populations, including specific studies of the effects of heavy metals, pesticides, and PCB's. McCormick et al. (1984) reviewed physical and sediment characteristics of Raritan Bay, studies of benthic organisms, plankton, and fish, and impact of pollution from sewage, organic chemicals, and heavy metals.

The present study was undertaken to assess potential impacts of contaminants in Raritan Bay on the spawning potential of hard clams. Monthly samples were collected from three study areas within the bay to obtain measurements of the shells, soft body tissues for observations of general condition, and gonadal tissues for observations of the reproductive cycle. Selected specimens were chosen to determine age and growth, and special tissue samples were collected for histochemical tests of certain metals. Published hydrographic conditions and assessment of pollutants in Raritan Bay are discussed in relation to sample results.

Methods

Campbell (1967) described the distribution of hard clams in Raritan Bay and, based on his findings, sites were chosen for repeated collections. The sites were Ward Point, New Dorp Beach, and Horseshoe Cove (Fig. 1). Each was sampled at about monthly intervals beginning on 21 February 1974 and ending on 7 April 1975. The clams were collected by towing a drag-type, nonhydraulic dredge with a 12-in (30 cm) wide knife from the U.S. National Marine Fisheries Service (NMFS) RV *Rorqual*. Tows were made at each site until 30 or more clams larger than 50 mm in shell length were caught. Special collections were made at Ward Point and New Dorp Beach on 1 November 1978 to obtain tissues for histochem-